

# Secure static content delivery for content distribution network using blockchain technology

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**Abstract**—A Content Distribution Network (CDN) is a new kind of network with the goal to distribute services and contents spatially relative to end-users to provide high availability and high performance. Several replicas of the Origin Server are used to reach this goal, but trust issues are now involved both between servers and among client and server. In this work is presented a new method to provide secure static content delivery using blockchain, a growing technology with the capability to ensure reliability and trust without a central authority.

Moreover, a prototype of the sistem has been developed on Ethereum private network, in order to test the feasibility. The test shows the goodness of the system, and the possibility to create a new content distribution model on the Internet.

## 1. Introduction

Contents distribution is one of the most important aspects of the Internet. To improve the distribution the Content Distribution Networks (CDNs) are born. CDNs provide high availability and high performance because many replicas (Edge Servers) of the Origin Server are spatially distributed to faster fulfill a request. Many services like CoralCDN [1] CoDeeN [2] provide the possibility to create a CDN starting from the Origin Server, replicating contents and distributing them to end users from the best Edge Server, likely the geographically nearest. A typical scenario can be seen in Figure 1, the Origin Server has more replicas to distribute contents.

In this scenario, two new trust issues are involved. First of all, an attacker could modify the contents from the Origin Server to the Edge Server, thus if the indirectly attacked Edge Server serves that modified content it will be labeled as a misbehaving replica. Secondly, if an Edge Server is not directly managed by the owner of the Origin Server, it can serve different content like stale content or outright modified content, adding ads for example. Furthermore in this architecture the Origin Server is a single point of failure. If the Origin server is compromised all the Servers will misbehave.

The main contribute of this work is two-fold.

First, it is suggested a new architecture to overcome the trust issue between servers, maintaining the CDN properties. Second, the proposed system provides a secure method to deliver static contents, ensuring the integrity with small effort on clients and Network.

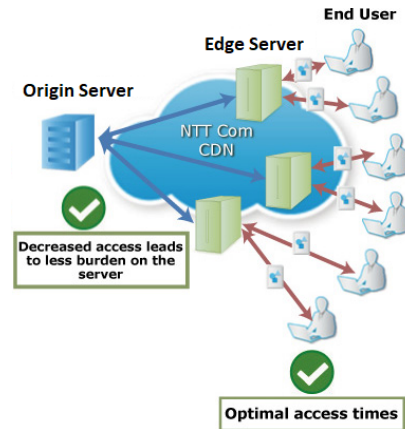


Figure 1. Typical CDN scenario where Origin Server has many Edge Servers to fulfill the clients requests.

## 2. Related Works

Checking the integrity of data retrieved from untrusted servers is a crucial problem nowadays. The typical approach for preventing contents tampering between clients and servers is to encrypt the end-to-end connection, for example, using the SSL protocol. This negates the functionality of the CDN, because the connection always requires the Origin Server, and the network is no more distributed. For static content, Merkle tree authentication [3] is a possible solution, where the server signs the content which is verified by the client. Also digital rights management schemes allows clients to verify data from untrusted server [4]. For dynamic content, [5] [6] propose the use of XML-based rules for managing the content, but it has to be limited to be easily verified by a client.

In peer-to-peer CDNs the problem is even more significant. LOCKSS [7] uses voting system for content integrity. Repeat the execution to detect misbehavior has been used in Rx [8] and in Vigilante [9] to discover bugs and worms respectively. These approaches require significant overhead on the client. In Pioneer [10] the verify effort is on the dispatcher, a trusted platform, but since the proof of correctness is extremely time sensitive it is not suitable for large scale systems. Finally Repeat and Compare system [11] is for both static and dynamic contents, it requires the repetition of the content to another replica and compares the results

to detect misbehaving replicas. However, the process has significant overhead, and the verify requests may overwhelm the network, thus only a fraction of the contents are verified. In this work blockchain technology is used. The structure of blockchain ensure trust between untrusted nodes without central authority. A system of contents distribution built over blockchain inherits all its benefits, making simple to share contents and verify them between clients and servers.

### 3. Blockchain Technology

After the rise of Bitcoin [12], its underlying structure, the blockchain technology, has been applied to a variety of usecases ranging from authentication [13] (using Ethereum and Smart Contracts) to medical reports [14]. Blockchain is based on append-only ledger, a growing list of records (called blocks) which are linked and secured using cryptography. The ledger can be viewed by all participating nodes and the updates are permitted only after the consensus of the network. Each block typically contains a cryptographic hash of the previous block, a timestamp and transaction data. Thanks to its structure and the proof-of-work required to create a new block, a blockchain is inherently resistant to modification of the data. A simple example of blockchain is shown in Figure 2.

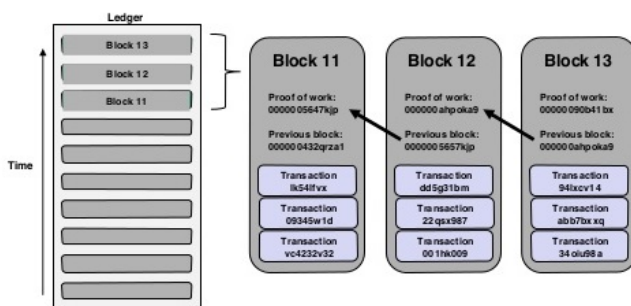


Figure 2. Example of blockchain. Transactions are stored in the blocks of the Ledger. Blocks are linked by hashes.

The presented system relies on Ethereum, an open-source, public, blockchain-based distributed computing platform, which allows to execute smart contracts, immutable programs always visible from the community.

#### 3.1. Ethereum

Ethereum [15] is described as a transactional singleton machine with shared-state. The distributed ledger can be view as a distributed virtual machine which records transactions and state changes. The blockchain is kept alive by the miners, nodes which have three main tasks:

- Verifying the transactions being sent, through the consensus algorithm which is similar to other blockchains, removing the need of central authority;

- Checking if the sender has sufficient gas, the Ethereum's native cryptocurrency, to transfer to the receiver;
- Running the function called by the sender and thus to modify the blockchain state accordingly.

In regards to the third point, we see the most important feature of Ethereum: encoding smart contracts.

**3.1.1. Smart Contracts.** Smart contracts describe functions, which can be called by nodes participating in the blockchain, and states which can be changed by the nodes. The functions run in the Ethereum Virtual Machine (EVM) which is described as a *quasi*-Turing complete computer able to execute code of any complexity. The *quasi* qualification comes from the fact that the computation is intrinsically bounded to *gas*, which limits the total amount of computation done. If the gas transferred to the miner for the function execution is less than the required amount, then the transaction is not mined.

The contract can use memory and storage to save data. It can use any amount of memory (paying gas) during executing its code, but when execution stops, the entire content of the memory is wiped. The storage on the other hand is persisted into the blockchain itself. It can be changed, but all the changes will be recorded in the ledger.

In the presented sytem, thanks of its persistence and (im)mutability, storage will be used to store and share contents.

#### 3.2. Benefits

In this paragraph, the benefits of using blockchain are discussed. Building the content delivery system on the blockchain it will inherit all the benefits.

- **Decentralization:** Consensus mechanism is used to agree on the validity of transactions, thus there is no need for a trusted third party;
- **Transparency and trust:** Blockchains are shared and visible from all the participants. This makes the system transparent and as a result trust is established;
- **Immutability:** Once the data has been written into the blockchain, it is extremely difficult to change it back. In Ethereum if the state is changed all the updates are stored in the ledger. If only few user are allowed to change the state, the state remains immutable as long as they don't change it;
- **High availability:** As the system is based on several nodes in a peer-to-peer network, and the data is replicated and updated on each node, the network as a whole continues to work even if nodes leave or become unavailable;
- **Highly secure:** All transactions on a blockchain are cryptographically secured and provide integrity.

## 4. System Design

In this section is presented the developed system to distribute and check integrity of the contents. Firstly an high-level overview is shown. Secondly more details about the architecture are provided. Lastly benefits and drawbacks of the system are discussed.

### 4.1. Overview

Figure 3 shows high-level view of how the presented system distributes the contents on the Servers and permits to Client to check integrity.

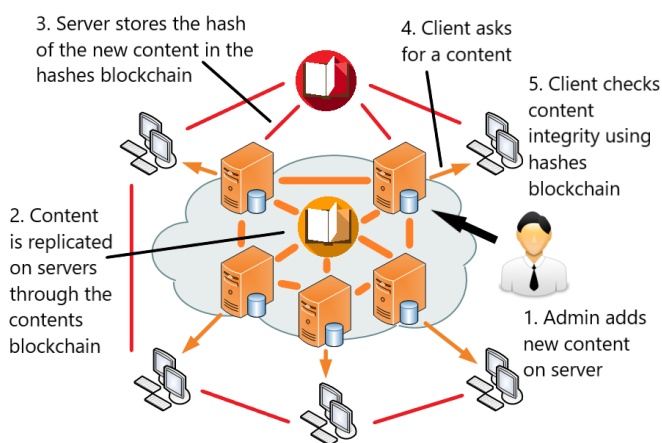


Figure 3. Overview of the content delivery and check system.

The system wants to resolve trust issues between Origin and Edge Servers, since the last can receive altered contents, and between Servers and Clients, as Server can send different content from the requested one. The key idea is to use two different blockchains: the *Contents Blockchain* and the *Hashes Blockchain*.

**4.1.1. Contents Blockchain.** The proposal is to build the CDN on a blockchain, the *Contents Blockchain*. This means each Edge Server is a node of the blockchain. The Origin Server is no more required, since it is possible to add a content from every node (Edge Server) as long as it is authorized, and the content will be automatically distributed on each Server thanks to blockchain technology. To authorize the upload of the contents an user system is used. Since the blockchain is always visible from every participant, and every participant has a public address, which is a public and private key pair, it is enough to store in the blockchain the addresses of who can upload the contents, and after checking who is requesting the upload, the transaction can be executed or not. Two kind of user are permitted: Admin and Super-admin. Admins can upload/remove/edit the contents while Superadmin can also create other Admins.

**4.1.2. Hashes Blockchain.** The *Hashes Blockchain* is the key to check the integrity of received contents. Thanks to hash functions is really simple to check message integrity [16]. An hash function is any function that can be used to map data of arbitrary size to data of fixed size. A cryptographic hash function allows one to easily verify that some input data maps to a given hash value, but if the input data is unknown, it is extremely difficult to reconstruct it by knowing the stored hash value. These property are very useful for the goal. Every time a content is uploaded, its hash is calculated by the Server and stored in the *Hashes Blockchain*, where the participants are both Servers and Clients. After the client receives the requested content it can easily check its integrity calculating its hash and comparing it with the one stored in the blockchain. If the hashes are equals the content is right, otherwise something wrong happend. Since storing the hash of a content requires the consensus of the network it is always correct, and there is no possibility for a server to change it without noticing the others nodes.

### 4.2. Typical Usage

A typical usecase is shown in Figure 3. First an Admin wants to upload a new content. After the system checks and authorizes him, a new upload request is sent among the *Contents Blockchain*. When the network approves the request, a copy of the content is distributed on each server (according to blockchain technology) and its hash is calculated and stored in the *Hashes Blockchain*. At any time a client can ask for that content. When the content is received the client calculate its hash with the same hash function used by the Servers and compares the obtained hash with the calculated one. If they are equals the integrity is verified, otherwise the client can reject the content and ask to another server.

### 4.3. Benefits and Drawbacks

**KEY IDEAS:** Simplification of current paradigms The current model in many industries such as finance or health is rather disorganized, wherein multiple entities maintain their own databases and data sharing can become very difficult due to the disparate nature of the systems. But as a blockchain can serve as a single shared ledger among interested parties, this can result in simplifying this model by reducing the complexity of managing the separate systems maintained by each entity.

In the financial industry, especially in post-trade settlement functions, blockchain can play a vital role by allowing the quicker settlement of trades as it does not require a lengthy process of verification, reconciliation, and clearance because a single version of agreed upon data is already available on a shared ledger between financial organizations.

## 5. Implementation

### 5.1. Contents Blockchain

### 5.2. Hashes Blockchain

## 6. Future Works

## 7. Conclusion

The conclusion goes here.

## Acknowledgments

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